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Technical Lesson 30

PRACTICAL RADIO CONSTRUCTION

Regeneration, as you know, may be secured only by returning to the grid circuit of the tube some of the amplified signal energy present in the plate circuit. By such means alone can regeneration and its allied phenomenon oscillation, be secured; and when such feed-back is absent or is reduced to a negligible amount, regeneration and oscillation cannot be obtained.

In the great majority of regenerative detector circuits this feed-back is secured by means of inductive coupling between plate and grid circuits and feed-back secured in this manner is termed inductive feed-back. However, there are a few circuits in existence wherein feed-back is effected through condensers, and is, therefore, termed capacity feed-back.

This lesson is a continuation of the work embodied in Lesson 28 insofar as it employs a regenerative vacuum tube detector. The receiver dealt with in that lesson employed inductive feed-back to secure regeneration. Furthermore, the tickler coil, by means of which the inductive feed-back was obtained, was made movable because, for reasons given therein, it is necessary to exercise control over the amount of feed-back - and this control was effected by rotating the tickler coil, thereby varying the coupling between it and the grid coil.

The receiver to be dealt with in this lesson employs regeneration; and this regeneration is secured in exactly the same manner as in Lesson 28; i.e., by means of a tickler coil which, by virtue of being inductively coupled to the grid coil, makes possible the necessary feed-back of energy from plate to grid circuits. This circuit differs, however, from that of Lesson 28 in the method employed to control the feed-back. Herein, the tickler is set in its position and control of feed-back is secured by varying the amount of radio frequency current flowing through the tickler coil.

A glance at Figure 1 will show that the plate circuit divides at point X to form two paths for the flow of current, the two paths being in parallel, one with the other. One path is from plate through the radio frequency choke coil, headphones and B battery to filament; the other path is from plate through the tickler coil and the variable condenser FC to filament.

Furthermore, we have present in the plate circuit two alternating currents of widely different frequency - one being a radio frequency current averaging 1,000,000 cycles per second; the other an audio frequency current averaging about 1,000 cycles per second.

The audio frequency component of the plate current is the electrical equivalent of the sound waves (voice and music) originating in the studio of the broadcasting station and, as the headphones are the electrical device whose sole purpose is to convert such currents to sound waves, it is immediately apparent that these audio frequency currents must be sent through that branch of the plate circuit which includes the headphones. On the other hand, it is necessary that the radio frequency component of the plate current flow through the branch of the plate circuit which includes the tickler coil in order that this radio frequency current can be utilized for securing regeneration. By the proper proportioning of the electrical dimensions of each of these two parallel branches of the plate circuit it is entirely possible to separate these audio and radio frequency currents and to confine each to that branch of the plate circuit in which it will do the work required of it and deliver the desired results.

The audio frequency component of the plate current upon reaching point X, will flow on through the headphones rather than through the other

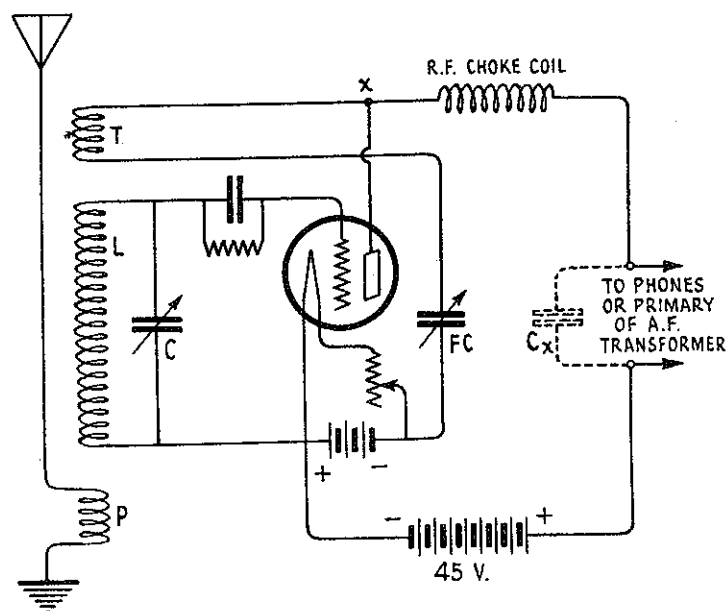


Figure 1

branch of the plate circuit which includes the variable condenser FC. Why the audio frequency current will take the path designated is apparent if the inductive and capacitive reactances of the various instruments involved are taken into consideration. At a frequency of 1000 cycles the inductive reactance of the headphones, which have an inductance, say, of three henries, is 18,840 ohms; whereas the capacitive reactance of condenser FC, which has a maximum capacity of .0005 mfd., is 322,580 ohms at the same frequency. Needless to

say, the audio frequency component of the plate current will follow the path of least reactance - through the headphones.

The radio frequency choke coil has an inductance of approximately 80 milli-henries (or .08 henry); therefore its inductive reactance at a frequency of 1,000 cycles is approximately 500 ohms, and so it offers little opposition to currents of audio frequency as compared to the much greater opposition created by the high inductance of the head-phones.

Let us again consider the inductive and capacitive reactances of these same instruments - but at a radio frequency of 1,000,000 cycles per second. At this frequency the inductive reactance of the radio frequency choke coil (80 milli-henries) is approximately 500,000 ohms, while the capacitive reactance of condenser FC (.0005 mfd.) is but 318 ohms. The radio frequency component of the plate current will flow through that branch of the plate circuit which offers the lesser opposition to its passage, i.e., through tickler coil and condenser FC. The inductance of the tickler coil is sufficiently low that its inductive reactance does not seriously impede the flow of radio frequency current.

Thus, by properly proportioning the values of inductance and capacity in the two parallel branches of the plate circuit the two currents are caused to separate at point X, each flowing in that branch of the plate circuit wherein it accomplishes the desired results.

It may occur to the student that it scarcely seems logical to insert in the circuit a radio frequency choke coil having an inductance of only 80 milli-henries (.08 henry) to prevent the passage of radio frequency current through the headphones which have an inductance of about three henries. At first glance, it would appear that such a comparatively high inductance as three henries would, in itself, constitute an inductive reactance of well-nigh infinite opposition to a frequency of 1,000,000 cycles per second; and such would be the case were it not for one factor - distributed capacity.

Like the audio frequency transformer primary mentioned in the preceding lesson, the headphone windings are composed of thousands of turns of very fine wire wound side by side and layer on layer. Here, then, we again encounter distributed capacity in coil windings and, exactly as in any coil, this distributed capacity does, in effect, form a shunt condenser across the winding.

Thus, any radio frequency current that reaches the headphones will not be subjected to the excessive inductive reactance of the head-phone windings for it will find a value of distributed capacity which will afford it an easy path through which to flow. A glance at Figure 1 will reveal that C_x (which represents the distributed capacity of the headphones) provides a path for radio frequency current directly from plate to filament circuit. This path is in parallel to the circuit composed of the tickler coil and feed-back control condenser FC so that any radio frequency current flowing through C_x will result in a decrease in the amount of radio frequency current flowing in the

tickler coil circuit. If the distributed capacity C_x is of sufficient value and it often is, it robs the tickler circuit of so much radio frequency current that it is impossible to secure regeneration.

Therefore, a radio frequency choke coil is inserted in the circuit at the point indicated in Figure 1 to prevent the radio frequency current from entering that branch of the circuit in which are included the headphones, and thus prevents the radio frequency current from being bypassed by the distributed capacity of the latter. In this manner the radio frequency choke coil prevents the distributed capacity of the headphones from short-circuiting the radio frequency current directly to the filament circuit by preventing, or "choking out", the radio frequency current from reaching this undesirable and troublesome distributed capacity.

All coils possess distributed capacity to a greater or lesser degree and radio frequency choke coils are by no means an exception to this rule. It should not be difficult to understand that any appreciable amount of distributed capacity in the radio frequency choke coil will greatly impair its "choking" action and thereby render it useless. It is of prime importance that, for a given value of inductance, the distributed capacity of this device be of as small a value as it is possible to make it; and to achieve this end special methods of winding are often employed.

The method of securing regeneration in this receiver is the same as that described in Lesson 28, namely, by means of a tickler coil. This circuit differs, however, from that described in Lesson 28 in the method employed to control the feed-back.

In the receiver of Lesson 28 control of feed-back was obtained by rotating the tickler coil and in this way varying the angle at which the grid coil was cut by the magnetic field of the tickler coil with a consequent variation of the inductive effect of the tickler upon the grid coil.

In this receiver the tickler coil, once it is adjusted to its proper position, need not again be moved, for control of regeneration is secured by varying the strength of the radio frequency current flowing therein. Here again is an application of the fundamentals of electromagnetic induction as set forth in preceding lessons. If the radio frequency current flowing through the tickler coil is decreased the magnetic field of the tickler is weakened, and this weakening of the tickler coil's magnetic field results in less energy being induced in the grid coil. In other words, a decrease in the strength of the radio frequency current flowing through the tickler results in decreased feed-back.

Conversely, an increase in the strength of the radio frequency current flowing through the tickler coil results in an increase in its magnetic field and, as this means that the grid coil is subjected to a stronger magnetic field, there will be an increase in the energy induced therein. Hence, an increase in the radio frequency current flowing through the

tickler coil results in increased feed-back. This control of the strength of the radio frequency current in the tickler coil is secured by employing a condenser, FC, in Figure 1, in series with the tickler coil; this condenser being continuously variable in its values of capacity from a minimum of about .00005 mfd. to its maximum of .0005 mfd.

Bear in mind that the reactance of any condenser is inversely proportional to its capacity, i.e., as its capacity increases its reactance decreases, and as its capacity decreases its reactance increases. Furthermore, the radio frequency current flowing through the tickler coil, will, of course, increase with a decrease in the capacitive reactance and will decrease with an increase in the capacitive reactance. This being so, then an increase in the capacity of the feed-back control condenser FC results in an increase in the feed-back, while a decrease in this condenser's capacity decreases the feed-back.

Here, then, we have a means of controlling feed-back which, by virtue of the fact that this condenser is continuously variable between its minimum and maximum values of capacity, affords us a smooth, even control of regeneration. In addition to this, such an arrangement for the control of feed-back possesses the decided advantage of having very little de-tuning effect upon the grid circuit. (Refer to Lesson 28 wherein it was pointed out that a rotatable tickler coil has a pronounced de-tuning effect upon the grid circuit).

In this circuit the tickler coil is stationary and thus exerts but little, if any, de-tuning effect upon the grid coil. The slight de-tuning effect which may result from varying the tickler coil's magnetic field by manipulating the feed-back control condenser, FC, is so slight as to be negligible. This absence of any appreciable de-tuning effect upon the grid circuit by the regeneration control is a very real advantage inasmuch as it renders the operation of the receiver simpler and easier.

Before commencing the wiring of this receiver remove all connections made in accordance with the instructions contained in Lesson 28. However, it is neither necessary nor desirable that the audio frequency amplifier be altered as we are dealing herein only with the connections in the radio frequency portion of the receiver.

Mount the feed-back control condenser on the panel to the right of the three-circuit tuner. The tuner, tuning condenser, rheostats and other apparatus retain the positions accorded them in the preceding lessons.

Begin by wiring in the filament circuit of the detector tube. A wire is run from the +A binding post on the terminal strip to the +A lug on the detector tube socket. A connection is now made between the -A binding post on the terminal strip and one of the terminals of the lower rheostat, the remaining terminal of this instrument being connected to

the -A lug of the detector tube socket. (No alteration is made in the connections of the upper rheostat as this is to continue to control the filament current of the audio amplifier tubes). Connect the antenna and ground binding posts to the terminals of the antenna coil of the tuner.

The tuning condenser should now be connected in parallel to the secondary of the tuner, taking care that the rotor plates of the condenser are connected to that end of the secondary which is nearest the antenna coil, and that the stator plates are connected to that end of the secondary farthest from the antenna coil. Connect the rotor plates of the tuning condenser to the positive A battery lead. One of the terminals of the grid condenser is now connected to the grid terminal of the detector tube socket, the remaining terminal of the grid condenser being connected to the stator plates of the tuning condenser. Do not forget to remove the grid leak from its clips on the grid condenser while soldering connections thereto.

The radio frequency choke coil should now be mounted to the rear of the baseboard and near the first stage audio frequency amplifying transformer. A wire is now run from the plate terminal of the detector tube socket to one of the tickler coil terminals. The remaining tickler coil terminal is connected to the stator plates of the feed-back control condenser, the rotor plates being connected to the negative A battery lead. The plate terminal of the detector tube socket is also connected to one of the radio frequency choke coil terminals. The remaining terminal of this choke coil is connected to the P terminal of the first stage audio frequency amplifying transformer, while the B terminal of this instrument is connected to the Det+B binding post on the terminal strip.

If the audio frequency amplifier is dispensed with and only the detector tube used, then the leads from the Det+B binding post and radio frequency choke coil are connected to the two tip jacks instead of to the primary terminals of the first audio frequency amplifying transformer. It is recommended, however, that the audio frequency amplifier be used.

This completes the wiring of the receiver. To put it in operation connect antenna, ground and batteries to their binding posts on the terminal strip.

As in the preceding hook-up (Lesson 29), the use of a C battery to furnish a grid biasing potential to the grids of the audio frequency amplifying tubes will depend upon the value of B battery voltage impressed upon the plates of these tubes. If a plate potential of 90 volts is used, a C battery of 4.5 volts should be connected to the C battery binding posts. However, if the plate potential of the amplifying tubes is made the same as that of the detector, i.e., 45 volts, no C battery is required. If the C battery is omitted it will be necessary to connect a short wire jumper from C+ to C- , otherwise the grid return lead of both audio frequency amplifying tubes would be open-circuited.

This receiver will be found to operate in a manner very similar to that of Lesson 28 inasmuch as the principles involved are identical except for

the means provided for controlling feed-back. (Bear in mind that feed-back is secured in the same manner - by means of a tickler coil. It is only the method of controlling it that differs). Tuning is accomplished by varying the capacity of the variable condenser connected in shunt to the tuner secondary, while feed-back is controlled by varying the capacity of the feed-back control condenser, FC.

When the receiver is first put in operation, set the feed-back control condenser at maximum capacity (rotor plates completely interleaved with stator plates) and set the tickler coil for maximum available coupling (tickler coil winding parallel to the grid coil winding). The receiver should now oscillate. Whether or not it is oscillating can be determined by listening for heterodyne squeals as the tuning condenser is slowly rotated, or by tapping the grid lead of the detector tube with a moistened finger tip. (See Lesson 28, sheet 16, paragraph 2). If the detector tube does not oscillate, turn the tickler coil around through one-half revolution so that it again is parallel to the grid coil, but thus reversing the polarity of the magnetic field acting upon the secondary.

Allowing the tickler coil to remain at this position of maximum coupling, feed-back can now be controlled by varying the capacity of feed-back control condenser; a reduction of its capacity resulting in a decrease in feed-back, while an increase in its capacity increases feed-back.

As always, the shorter the wavelength to which the grid circuit is tuned the less will be the feed-back necessary for maximum regeneration; and, conversely, the longer the wavelength to which the grid circuit is resonated the greater will be the amount of feed-back which will give regeneration.

After tuning in a number of stations and noting the settings of the feed-back control condenser which give regeneration at the various wavelengths to which the grid circuit is tuned, try varying the tickler coil coupling to determine the relationship between tickler coupling and feed-back control condenser.

To do this, tune in a station (preferably one on about 350 meters) with the tickler coil parallel to the grid coil (maximum tickler coupling) and the feed-back condenser adjusted for optimum regeneration. Now slightly reduce the tickler coupling; naturally, regeneration immediately decreases. The detector tube can now be brought back to the point of optimum regeneration, however, by increasing the capacity of the feed-back control condenser.

This, of course, is readily explainable. When the tickler coupling is decreased, the angle at which its magnetic field cuts the grid

coil is decreased with a consequent lessening of the inductive effect by the tickler upon the grid coil. The resultant decrease in the feed-back can be compensated by increasing the strength of the tickler coil's magnetic field. This is done by increasing the capacity of the feed-back control condenser which, because it thereby permits more radio frequency current to flow through the tickler coil, strengthens the magnetic field thereof.

Try different values of tickler coupling and note the corresponding changes in the adjustment of the feed-back control condenser necessary to maintain the detector tube at the point of maximum regeneration. As the tickler coupling is reduced it will be found, when a certain degree of coupling is reached, that it is impossible to secure regeneration at the longer wavelengths even when the feed-back control condenser is adjusted to maximum capacity. Such a circumstance indicates that, although the tickler coil is receiving all the radio frequency current available in the plate circuit, yet its coupling to the grid coil is too loose to give the amount of feed-back required for regeneration at the longer wavelengths. As the tickler coupling is still further reduced - and this reduction should be gradual - it will be found that the highest wavelength at which regeneration can be secured becomes less and less until, as the tickler coupling approaches zero, it will be found impossible to secure regeneration even at the shorter wavelengths where the least amount of feed-back is necessary to secure regeneration. When the tickler coil is at, or nearly at, right angles to the grid coil its coupling is practically zero; therefore, even if a comparatively strong radio frequency current flows through the tickler coil, its inductive effect upon the grid coil is negligible and, therefore, feed-back is non-existent.

After experimenting with the adjustment of the feed-back control condenser as related to different values of tickler coupling, as outlined above, no difficulty should be experienced in determining a value of tickler coupling at which the control of feed-back "spreads" over most of the feed-back control condenser's dial. That is to say, regeneration at the longer wavelengths (about 500 meters) should be secured at about 70 or 75 on the regeneration control dial, while regeneration at the shorter wavelengths in the vicinity of 200 meters should be obtained at about 20 or 25 on this dial. This is the adjustment which will give the smoothest, easiest control of regeneration.

If this receiver were to be a permanent one, the length of bakelite tubing on which the tickler coil is wound would be rigidly mounted inside the secondary coil of the tuner; or else it would be wound on the same tube as the secondary and with little or no spacing between the tickler and secondary windings. Thus, if the tickler were fixed in its position, the adjustment of its coupling in order to "spread" the regeneration control over most of its dial would, of necessity, have to be made by adding turns to, or subtracting turns from, the tickler winding.

EXAMINATION - LESSON 30

1. Why is it necessary that the radio frequency component of the detector tube's plate current flow through the tickler coil?
2. Why is the radio frequency choke coil used?
3. How is feed-back secured in this receiver?
4. Why is it necessary that the audio frequency component of the detector tube's plate current flow through the headphones?
5. How does the feed-back control condenser control the feed-back in this receiver?
6. What is the advantage of this method of controlling regeneration?
7. What effect upon feed-back accompanies an increase in the capacity of the feed-back control condenser?
8. In any receiver employing this method of controlling regeneration, is it necessary that the tickler coil be movable?
9. What kind or type of coils possess distributed capacity?
10. Does a decrease in the strength of the radio frequency current flowing through the tickler coil result in increased or decreased feed-back?